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HANS MARTIN HERTZ et al.	)	Group Art Unit: 2882
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For: METHOD AND APPARATUS FOR GENERATING X-RAY OR EUV RADIATION	)	

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CLAIM FOR CONVENTION PRIORITY

Assistant Commissioner for Patents
Washington, D.C. 20231

Sir:

The benefit of the filing date of the following prior foreign Patent Application in the following foreign country is hereby requested, and the right of priority provided in 35 U.S.C. § 119 is hereby claimed:

Swedish Patent Application No. 0002785-4

Filed: July 28, 2000

In support of this claim, enclosed is a certified copy of said prior foreign Patent Application. Said prior foreign Patent Application is referred to in the oath or declaration. Acknowledgment of receipt of the certified copy is requested.

Respectfully submitted,

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Patentavdelningen

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METHOD AND APPARATUS FOR GENERATING X-RAY OR EUV RADIATION AS WELL AS USE THEREOF

Technical Field

The present invention generally relates to a method and an apparatus for generating X-ray or extreme ultraviolet (EUV) radiation, especially with high brilliance. The generated radiation can for example be used in medical diagnosis, non-destructive testing, lithography, microscopy, materials science, or in some other X-ray or EUV application.

Background Art

X-ray sources of high power and brilliance are applied in many fields, for instance medical diagnosis, non-destructive testing, crystal structural analysis, surface physics, lithography, and microscopy.

In some applications, X-rays are used for imaging the interior of objects that are opaque to visible light, for example in medical diagnostics and material inspection, where 10-1000 keV X-ray radiation is utilized, i.e. hard X-ray radiation. Conventional hard X-ray sources, in which an electron beam is accelerated towards a solid anode, generate X-ray radiation of relatively low brilliance. In hard X-ray imaging, the resolution of the obtained image basically depends on the distance to the X-ray source and the size of the source. The exposure time depends on the distance to the source and the power of the source. In practice, this makes X-ray imaging a trade-off between resolution and exposure time. The challenge has always been to extract as much X-ray power as possible from as small a source as possible, i.e. high brilliance. In conventional solid-target sources, X-rays are emitted both as continuous bremsstrahlung and characteristic line emission depending on the target material used. The energy that is not

converted into X-ray radiation is primarily deposited as heat in the solid target. The primary factor limiting the power, and the brilliance, of the X-ray radiation emitted from a conventional X-ray tube is the heating of the anode. If too much electron-beam power is used, the anode will be damaged. Several different schemes have been introduced to increase the power limit. One such scheme includes cooling and rotating the anode, see for example "Imaging Systems for Medical Diagnostics", E. Krestel, Siemens Aktiengesellschaft, Berlin and Munich, 1990. Although the cooled rotating anode can sustain a higher electron-beam power, its brilliance is still limited by the localized heating of the electron-beam focal spot. Also the average power load is limited since the same target material is used on every revolution. Typically, very high intensity sources for medical diagnosis operate at 100 kW/mm^2, and state of the art low-power micro-focus devices operate at 150 kW/mm^2.

Applications in the soft X-ray and EUV wavelength region (a few tens of eV to a few keV) include, e.g., next generation lithography and X-ray microscopy systems. Ever since the 1960s, the size of the structures that constitute the basis of integrated electronic circuits has decreased continuously. The advantage thereof is faster and more complex circuits requiring less power. At present, photolithography is used to industrially produce such circuits having a line width of about 0.13 μm. This technique can be expected to be applicable down to about 0.1-0.07 μm. In order to further reduce the line width, other methods will probably be necessary, of which EUV projection lithography is a strong candidate, see for example "International Technology Roadmap for Semiconductors", International SEMATECH, Austin TX, 1999. In EUV projection lithography use is made of a reducing EUV objective system in the wavelength range around 10-20 nm. In the soft X-ray and EUV region, compared to the conventional generation of hard X-ray radiation as

discussed above, a different scheme for generation of radiation is normally used since the direct conversion from electron-beam energy into soft X-ray radiation, in solid targets, generally is too low to be useful. A common technique for generation of soft X-ray and EUV radiation is instead based on ionization of the target material for production of a hot, dense plasma using intense (around 10^{10}-10^{13} W/cm^2) laser radiation, such as disclosed in "Soft X-rays and Extreme Ultraviolet Radiation: principles and application", D.T. Attwood, Cambridge University Press, 1999, and in "X-rays from Laser-plasmas: generation and applications", Turcu et al, John Wiley & Sons, West Sussex, 1999. These so-called laser produced plasmas (LPP) emit both continuous radiation and characteristic line emission depending on target material and plasma temperature. Traditional LPP X-ray sources, using a solid target material, are hampered by unwanted emission of debris as well as limitations on repetition rate and uninterrupted usage, since the delivery of target material becomes a limiting factor. This has lead to the development of regenerative, low debris targets including gas jets (see for example US-A-5 577 092, and the article "Debris-free EUVL sources based on gas jets" by Kubiak et al, published in OSA Trends in Optics and Photonics, No. 4, p. 66, 1996), and liquid jets (see for example US-A-6 002 744, and the article "Liquid-jet target for laser-plasma soft x-ray generation" by Malmqvist et al, published in Review of Scientific Instruments, No. 67, p. 4150, 1996). These targets have been extensively used in LPP soft X-ray and EUV sources. However, the applicability of LPP sources is limited by the relatively low conversion efficiency of electrical energy into laser light and then of laser light into X-ray radiation, necessitating the use of expensive high-power lasers.

There are also large facilities such as synchrotron light sources, which produce X-ray radiation with high

average power and brilliance. However, there are many applications that require compact, small-scale systems that produce X-ray radiation with a relatively high average power and brilliance. Compact and more inexpensive systems yield better accessibility to the applied user and thus are of potentially greater value to science and society.

Some work has also been done on electron-beam excitation of a gas-jet target for direct conversion in the soft X-ray region, see Ter-Avertisyan et al, Proceedings of the SPIE, No. 4060, p. 204, 2000. Unfortunately the use of a low density gas target in combination with direct conversion results in low power and low brilliance.

Summary of the Invention

It is an object of the present invention to solve or alleviate the problems described above. More specifically, the invention aims at providing a method and an apparatus for generation of X-ray or EUV radiation with very high brilliance in combination with relatively high average power.

It is also an object of the invention to provide a compact and relatively inexpensive apparatus for generation of X-ray or EUV radiation.

The inventive technique should also provide for stable and uncomplicated generation of X-ray or EUV radiation, with minimum production of debris.

A further objective is to provide a method and an apparatus generating radiation suitable for medical diagnosis and material inspection.

Still another object of the invention is to provide a method and an apparatus suitable for use in lithography, non-destructive testing, microscopy, crystal analysis, surface physics, materials science, X-ray photo spectroscopy (XPS), and other X-ray applications.

These and other objectives, which will be apparent from the following description, are wholly or partially

achieved by the method and the apparatus according to independent claims 1 and 13, respectively. The dependent claims define preferred embodiments.

According to the invention, at least one electron beam is directed onto a jet which is generated from a liquid substance. Thereby, the beam interacts with the jet to generate X-ray and/or EUV radiation. The liquid jet target combines the advantage of having the high-density of the conventional anode with the regenerative character of low-density gas jet targets. Thus, the electron-beam power density at the target may be increased significantly compared to non-regenerative targets, resulting in a source with higher brilliance. Depending on the type of liquid substance, the temperature, speed and diameter of the jet, as well as on the current, voltage and focal spot size of the electron beam, the method and apparatus may be operated in either of two modes. In a first mode of operation, radiation is generated by direct conversion of the electron-beam energy to bremsstrahlung and characteristic line emission, essentially without ionizing the jet. In the second mode of operation, radiation is generated by heating the jet to a plasma-forming temperature.

In the first mode of operation, one advantage of using a small, high density, high Z, regenerative target in the form of a liquid jet resides in the opportunity to operate the electron source with a high power density of the electron-beam on the target, still essentially without ionizing or evaporating the same. Thus, the first mode of operation provides for generation of hard X-ray radiation with high brilliance, higher than is possible with, e.g., rotating anode targets since the electron-beam power density may be raised above the damage threshold of the rotating anode. In order to achieve the power density allowed for by this novel, regenerative target, the electron beam should preferably be properly focused thereon. Typically, the acceleration voltage used

for generating the electron beam will be in the order of 5-500 kV, but might be higher. The beam current will typically be in the order of 10-1000 mA, but might be higher.

In the second mode of operation, advantages of using a target in the form of a liquid jet include low emission of debris, essentially no limitation on repetition rate and uninterrupted usage, as well as better wall-plug efficiency, lower cost and complexity of electron sources compared to lasers. In the second mode of operation, the electron source should deliver in the order of 10^{10}-10^{13} W/cm^2 to the area of interaction in order to establish the desired plasma temperature. This could be easily achieved by operating the electron source to generate a pulsed electron beam, wherein the pulse length should be matched to the size of the jet. The repetition rate of the electron source then determines the average power of the generated X-ray or EUV radiation.

In both modes of operation, for optimum utilization of the accessible electron beam power, the beam is preferably focused on the jet to essentially match the size of the beam to the size of the jet. In this context it is possible to use a line focus instead of a point focus, the transverse dimensions of the line focus being essentially matched to the transverse dimensions of the jet. The jet is preferably generated with a diameter of about 1-100 μm but may be as large as millimeters. Thereby, the radiation will be emitted with high brilliance from a small area of interaction.

The liquid substance is not limited to materials normally in a liquid state, but may also include a solid, for example a metal, heated to a liquid state, or a gas, for example a noble gas, cooled to a liquid state. Alternatively, the liquid substance can comprise materials dissolved in a carrier liquid.

Preferably, the jet is generated by urging the liquid substance through an outlet, such as a nozzle or

an orifice, typically by means of a pump and/or a pressurized reservoir yielding a pressure typically in the range of 0.5-500 MPa to bring about a jet propagation speed of about 10-1000 m/s from the outlet. The large span of operating parameters for the jet means that the jet may attain different hydrodynamic states. Slow jets are normally laminar and break up into droplets under the influence of surface tension while fast jets are more or less turbulent and are only spatially continuous in a transitional region before they turn into a spray. Any type of hydrodynamic state of the jet may be employed with the inventive technique. Further, depending on the type of liquid substance, the jet may be electrically conductive or not. This has implications on the away transport of electrons deposited in the jet and may thus influence, e.g., electron-beam focusing. It is also conceivable to allow the jet to freeze before interacting with the electron beam.

The gas atmosphere may vary within the inventive apparatus. The necessary layout of the gas atmosphere in the apparatus depends on both the desired wavelength of the generated radiation and the type of electron source. Typically, the need for a vacuum environment is higher at the electron source than at the area of interaction. It is possible to use localized gas pressures and differential pumping schemes to maintain different pressures in different parts of the apparatus.

Brief Description of the Drawing

The invention will now be described for the purpose of exemplification with reference to the accompanying drawing, which illustrates a currently preferred embodiment and is a schematic view of an inventive apparatus for generating X-ray or EUV radiation by interaction of an electron beam and a liquid jet.

Description of Preferred Embodiments

The apparatus shown in the drawing includes a chamber 1, an electron source 2, and a target generator

3. The electron source 2 is arranged to emit a pulsed or continuous electron beam 4 into the chamber 1 and focus the beam 4 on a target 5, which is generated by the target generator 3. Although not shown on the drawing, more than one electron beam 4 may be generated, the beams 4 being focused from one or more directions on the target 5. The electron source 2, which incorporates acceleration and focusing elements (not shown), can be of conventional construction and is powered by a voltage power supply 6. Depending on the desired characteristics of the electron beam 4, the electron source 2 might be anything from a simple cathode source to a complex high-energy source such as a racetrack.

As will be further described below, X-ray or EUV radiation (indicated by arrows in the drawing) is generated by the beam 4 interacting with the target 5 inside the chamber 1. Normally, a vacuum environment is provided in the chamber 1, due to requirements of the electron source 2. Furthermore, the high absorption of soft X-ray and EUV radiation in matter often necessitates a high-vacuum environment.

For the formation of a microscopic and spatially stable target 5 in a vacuum environment, the target generator 3 is arranged to generate a spatially continuous jet 5 from a liquid substance. The target generator 3 shown in the drawing includes a reservoir 7 and a jet-forming outlet opening 8, typically a nozzle opening, which is connected to a liquid outlet of the reservoir 7 and opens in the chamber 1. The reservoir 7 holds the substance from which the jet 5 is to be formed. Depending on the type of substance, the reservoir 7 can be provided with cooling or heating elements (not shown) to maintain the substance in a liquid state while it is being urged through the outlet opening 8 at high pressure, normally 0.5-500 MPa, typically by feeding high-pressure gas to a gas inlet 12 of the reservoir 7. The diameter of the outlet opening 8 is typically smaller

than about 100 μm. The resulting jet 5, which is stable and microscopic and has essentially the same diameter as the outlet opening 8, typically propagates at a speed of about 10-1000 m/s in the chamber 1. Although not shown in the drawing, the jet 5 could propagate to a break-up point where it spontaneously breaks up into droplets or a spray, depending on the operating parameters of the target generator 3. The distance to the break-up point is essentially determined by the hydrodynamic properties of the liquid substance, the dimensions of the outlet 8 and the speed of the liquid substance.

When the liquid substance leaves the outlet opening 8, it is cooled by evaporation. It is therefore conceivable that the jet 5 may freeze, such that no droplets or sprays are formed.

As shown in the drawing, the electron beam 4 impinges on the jet 5 before the jet 5 spontaneously, or by stimulation, breaks up into droplets, i.e. while it is still a small collimated jet. Thus, the area of interaction 9 between the beam 4 and the jet 5 is located on a spatially continuous portion of the jet 5, i.e. a portion having a length that significantly exceeds the diameter. Thereby, the apparatus can be continuously or semi-continuously operated to generate X-ray or EUV radiation, as will be described below. Further, this approach results in sufficient spatial stability of the jet 5 to permit the focal spot of the electron beam 4 on the jet 5 to be of approximately the same size as the diameter of the jet 5. In the case of a pulsed electron beam 4, this approach also alleviates the need for any temporal synchronization of the electron source 2 with the target generator 3. In some cases, similar advantages can be obtained with jets consisting of separate, spatially continuous portions. It should be emphasized, however, that any formation emanating from a liquid jet can be used as target for the electron-beam within the

scope of the invention, be it liquid or solid, spatially continuous, drops, or a spray.

By properly adapting the characteristics of the electron beam 4 in relation to the characteristics of the target 5, the interaction of the beam 4 with the jet 5 results, in a first mode of operation, in that radiation is emitted from the area of interaction 9 by direct conversion, essentially without any ionization of the jet 5. In a second mode of operation, these characteristics are adapted such that the jet 5 is ionized to form a radiation-emitting plasma. The choice of mode depends on the desired wavelength range of the generated radiation. A plasma-based operation is most effective for generating soft X-ray and EUV radiation, i.e. in the range from a few tens of eV to a few keV, whereas as an essentially non-plasma, direct conversion operation is more efficient for generation of harder X-rays, typically in the range from about 10 keV to about 1000 keV.

In the following, the operation of the apparatus in the first and second modes will be discussed in general terms. Examples of conceivable realizations are also given, without limiting the disclosure to these examples.

In the first mode of operation, which is primarily intended for generation of hard X-ray radiation to be used in, inter alia, medical diagnosis, the electron source 2 is controlled in such a manner, in relation to the characteristics of the target 5, that essentially no plasma is formed at the area of interaction 9. Thereby, hard X-ray radiation is obtained via bremsstrahlung and characteristic line emission. It is preferred that the distance from the outlet opening 8 to the area of interaction 9 is sufficiently long, so that the beam-jet-interaction does not damage the outlet. In one conceivable realization, use is made of a jet 5 of liquid metal having a diameter of about 30 μm and a propagation speed of about 600 m/s, the jet 5 being irradiated about 10 mm away from the outlet opening 8 by means of an

electron beam 4 of about 100 mA and 100 kV, the beam 4 being focused on the jet 5 to obtain a power density of about 10 MW/mm^2 in the area of interaction 9. This power density is roughly a factor of 100 better than in conventional solid-target systems, as discussed by way of introduction. By means of the invention, a high-resolution image can be obtained with a low exposure time. In this first mode of operation, the jet 5 is preferably formed from metals heated to a liquid state. In this context, tin (Sn) should be easy to use, although other metals or alloys may be used for generation of radiation in a desired wavelength range. Further, it is also conceivable to use completely different substances for generating the jet 5, such as gases cooled to a liquid state or material dissolved in a carrier liquid.

The apparatus operating in the first mode can include a window (not shown) transparent to X-rays for extracting the generated radiation from the chamber 1 to the exterior where patients, or other objects, can be imaged. By using a microscopic liquid jet 5 as a target, the size of the X-ray radiation is generated from a very small area of interaction 9, resulting in a high brilliance.

In the second mode of operation, which is primarily intended for generation of soft X-ray and/or EUV radiation to be used in, inter alia, EUV projection lithography, the electron source 2 is controlled in such a manner, in relation to the characteristics of the target 5, that a plasma is formed at the area of interaction 9. Thereby, soft X-ray radiation and EUV radiation is obtained via continuous and characteristic line emission. Preferably, a pulsed electron beam 4 irradiates the jet 5, whereby the electron source 2 is controlled to form a plasma by every electron-beam pulse. It is preferred that the distance from the outlet opening 8 to the point of interaction 9 is sufficiently long, so that the created plasma does not damage the outlet. In

one conceivable realization, use is made of a jet 5 of liquid noble gas having a diameter of about 30 μm and a propagation speed of about 50 m/s, the jet 5 being irradiated about 10 mm away from the outlet opening 8 by means of a pulsed electron beam 4 of about 10 A and 1 MeV operated at a repetition rate of about 50 kHz with a pulse length of about 5 ns, the beam 4 being focused on the jet 5 to obtain a power density of about 10^{12} W/cm^2 per pulse in the area of interaction 9 and an average electron beam power of 2.5 kW. Such a system would roughly provide the EUV power needed for the next generation EUV projection lithography systems.

In this second mode of operation, the specific characteristics of the electron beam 4 are not crucial as long as the average power thereof is high enough and the pulse power and pulse time are matched to the target size in order to obtain the appropriate plasma-forming temperature in the area of interaction 9. In the second mode of operation, the jet 5 is preferably formed from a noble gas cooled to a liquid state, to avoid coating of sensitive components within the apparatus. For example, it is known from laser-plasma studies that liquefied xenon results in strong X-ray emission in the wavelength range of 10-12 nm (see for example the article "Xenon liquid-jet laser-plasma source for EUV lithography" by Hansson et al, published in Proceedings of the SPIE, vol. 3997, 2000). Besides liquefied noble gases, it is conceivable to use completely different substances for generating the jet, such as material dissolved in a carrier liquid or liquefied metals.

An apparatus operating in the second mode and being designed for use in lithography or microscopy can include a collector system of multi-layer mirrors (not shown) that collects a large portion of the created EUV or soft x-ray radiation and transports it to illumination optics and the rest of the lithography/microscopy system. By using a microscopic target in the form of a jet 5

generated from a liquid substance, the production of debris will be very low. The inventive apparatus operating in the second mode has the potential of providing the same performance as a LPP system but at a lower price since multi kilowatt lasers are very complicated and expensive. Furthermore, the wall-plug conversion efficiency is much higher for electron sources than for lasers.

It should also be noted that, when the electron source 2 is operated for first-mode x-ray generation and/or emits pulsed electron radiation, a large portion of the liquid substance may remain unaffected by the electron beam 4 and propagate unhindered through the chamber 1. This would result in an increase of pressure in the vacuum chamber 1 owing to evaporation. This problem can be solved, for instance, by a using a differential pumping scheme, indicated in the drawing, where the jet 5 is collected at a small aperture 10 and then recycled to the reservoir 7 by means of a pump 11 that compresses the collected substance and feeds it back to the reservoir 7.

CLAIMS

1. A method for generating X-ray or EUV radiation, comprising the steps of generating a jet (5) from a liquid substance, and directing at least one electron beam (4) onto the jet (5), the beam (4) interacting with the jet (5) to generate said X-ray or EUV radiation.

2. A method according to claim 1, comprising the further step of controlling the electron beam (4) to interact with the jet (5) essentially without ionizing the same, such that bremsstrahlung and characteristic line emission is generated in the hard X-ray region.

3. A method according to claim 1, comprising the further step of controlling the electron beam (4) to interact with the jet (5) by heating the same to a plasma-forming temperature, such that soft X-ray radiation or EUV radiation is generated.

4. A method according to any one of the preceding claims, wherein the liquid substance comprises a solid, preferably a metal, heated to a liquid state.

5. A method according to any one of the preceding claims, wherein the liquid substance comprises a gas, preferably a noble gas, cooled to a liquid state.

6. A method according to any one of the preceding claims, wherein the jet (5) is generated by urging the liquid substance through an outlet (8), the jet (5) propagating from the outlet (8) towards an area of interaction (9), where it, independent of its current state, interacts with the electron beam (4).

7. A method according to any one of the preceding claims, wherein the electron beam (4) interacts with the jet (5) at a distance in the order of 0.5-10 mm from the outlet (8).

8. A method according to any one of the preceding claims, wherein the electron beam (4) is focused on the jet (5) to essentially match a transverse dimension of

the electron beam (4) to a transverse dimension of the jet (5).

9. A method according to any one of the preceding claims, wherein the jet (5) is generated with a diameter of about 1-10000 µm.

10. A method according to any one of the preceding claims, wherein the electron beam (4) is generated by means of an acceleration voltage in the order of 5-500 kV with a beam current in the order of 10-1000 mA.

11. A method according to any one of the preceding claims, wherein at least one pulsed electron beam (4) is directed onto the jet (5).

12. A method according to any one of the preceding claims, wherein at least continuous electron beam (4) is directed onto the jet (5).

13. An apparatus for generating X-ray or EUV radiation, comprising a target generator (3) for generating a jet (5) from a liquid substance, an electron source (2) for providing at least one electron beam (4) and directing the at least one electron beam (4) onto the jet (5), said radiation being generated by the beam (4) interacting with the jet (5).

14. An apparatus according to claim 13, wherein the electron source (2) is controllable to effect interaction of the electron beam (4) with the jet (5) essentially without ionization of the jet (5), to thereby generate bremsstrahlung and characteristic line emission in the hard X-ray region.

15. An apparatus according to claim 13, wherein the energy source (2) is controllable to effect interaction of the electron beam (4) with the jet (5) with heating of the jet(5) to a plasma-forming temperature, to thereby generate soft X-ray radiation or EUV radiation.

16. An apparatus according to any one of claims 13-15, wherein the liquid substance comprises a solid, preferably a metal, heated to a liquid state.

17. An apparatus according to any one of claims 13-16, wherein the liquid substance comprises a gas, preferably a noble gas, cooled to a liquid state.

18. An apparatus according to any one of claims 13-17, wherein the target generator (3) is adapted to urge the liquid substance through an outlet (8) to generate the jet (5) and propagate the same towards an area of interaction (9), where it, independent of its current state, interacts with the beam (4).

19. An apparatus according to any one claims 13-18, wherein the electron source (2) is controllable to direct the electron beam (4) onto the jet (5) at a distance in the order of 0.5-10 mm from the outlet (8).

20. An apparatus according to any one claims 13-19, wherein the electron source (2) is controllable to essentially match a transverse dimension of the electron beam (4) to a transverse dimension of the jet (5) by focusing the electron beam (4) on the jet (5).

21. An apparatus according to any one of claims 13-20, wherein the target generator (3) is adapted to generate the jet (5) with a diameter of about 1-10000 μm.

22. An apparatus according to any one of claims 13-21, wherein the electron source (2) is controllable to generate the electron beam (4) by means of an acceleration voltage in the order of 5-500 kV, thereby producing an electron beam (4) with a beam current in the order of 10-1000 mA.

23. An apparatus according to any one of claims 13-22, wherein the electron source (2) is controllable for generation of at least one pulsed electron beam (4).

24. An apparatus according to any one of claims 13-23, wherein the electron source (2) is controllable for generation of at least one continuous electron beam (4).

25. Use of the radiation generated by a method according to any one of claims 1-12 or an apparatus according to any one of claim 13-24 for medical diagnosis.

26. Use of the radiation generated by a method according to any one of claims 1-12 or an apparatus according to any one of claim 13-24 for non-destructive testing.

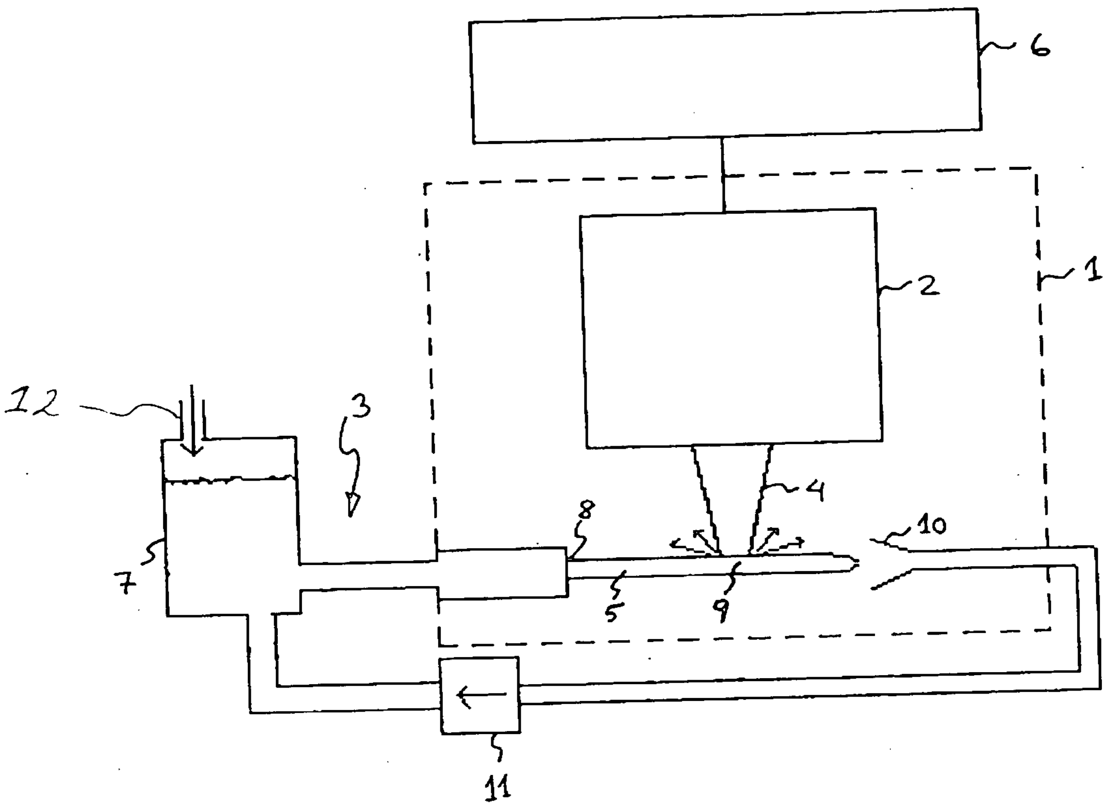
27. Use of the radiation generated by a method according to any one of claims 1-12 or an apparatus according to any one of claim 13-24 for EUV projection lithography.

28. Use of the radiation generated by a method according to any one of claims 1-12 or an apparatus according to any one of claim 13-24 for crystal analysis.

29. Use of the radiation generated by a method according to any one of claims 1-12 or an apparatus according to any one of claim 13-24 for microscopy.

ABSTRACT

A method for generating X-ray or EUV radiation, comprising the steps of generating a target (5) from a liquid substance, and directing at least one electron beam (4) onto the target. The electron beam (4) interacts with the target (5), emanating from a liquid-jet, to generate said X-ray or EUV radiation. An apparatus for generating X-ray or EUV radiation, comprising a target generator (3) for generating a liquid-jet (5) from a liquid substance, an electron source (2) for providing at least one electron beam (4) and directing said electron beam (4) onto the target (5), said radiation being generated by the beam (4) interacting with the jet (5).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